Chesapeake Hypoxia Analysis & Modeling Program (CHAMP):

Predicting impacts of climate change on the success of management actions in reducing Chesapeake Bay hypoxia

CHAMP PIs:

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Ray Najjar (PSU)
Lewis Linker (CBP/EPA)
Gary Shenk (CBP/USGS)
Hanqin Tian (Auburn)
Eileen Hofmann (ODU)

CHAMP MTAG:

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Bruce Michael
James Davis-Martin
Beth McGee
Mark Bennett
Dinorah Dalmasy
Susan Julius
Lee Currey

Fall 2016 – Fall 2021

CHAMP goals

Develop a Chesapeake Bay scenario-forecast modeling system to:

- Isolate future impacts on Chesapeake hypoxia of *climate change* from those due to *anthropogenic nutrient inputs*

- Determine whether the WIPs/TMDLs will successfully reduce hypoxia (and meet WQS) under future climate conditions

CHAMP models

Use <u>*multiple models*</u> in Chesapeake scenario-forecast modeling system:

- <u>Two</u> watershed models:
  - CBP WSMp6 (**CBP: Bhatt/Shenk**)
  - DLEM (**Auburn: H. Tian**)

Four model combinations

- <u>Two</u> estuarine models:
  - CBP WQSTM (**CBP: R. Tian/Linker**)
  - ChesROMS-ECB (**VIMS: Friedrichs**)

- Oyster population model (**ODU: Hofmann**)
  - To examine impact of hypoxia on living resources

CHAMP simulations

Four types of watershed+estuarine simulations:

- Realistic hindcasts (1985-2016)
- Future simulations (2025, 2050)
- Factorial future simulations
  - climate change vs. land use/population change
- Decision support: alternative management scenarios

All models must use same forcing:

- Future climate forcing: Atm temp, humidity, precip, winds, solar radiation
  - Downscaling technique - MACA vs. BCSD
  - CO_2 emissions scenario - RCP 8.5 vs. 4.5
  - ~20 GCMs
- Future atmospheric deposition
- Future Population/land use change

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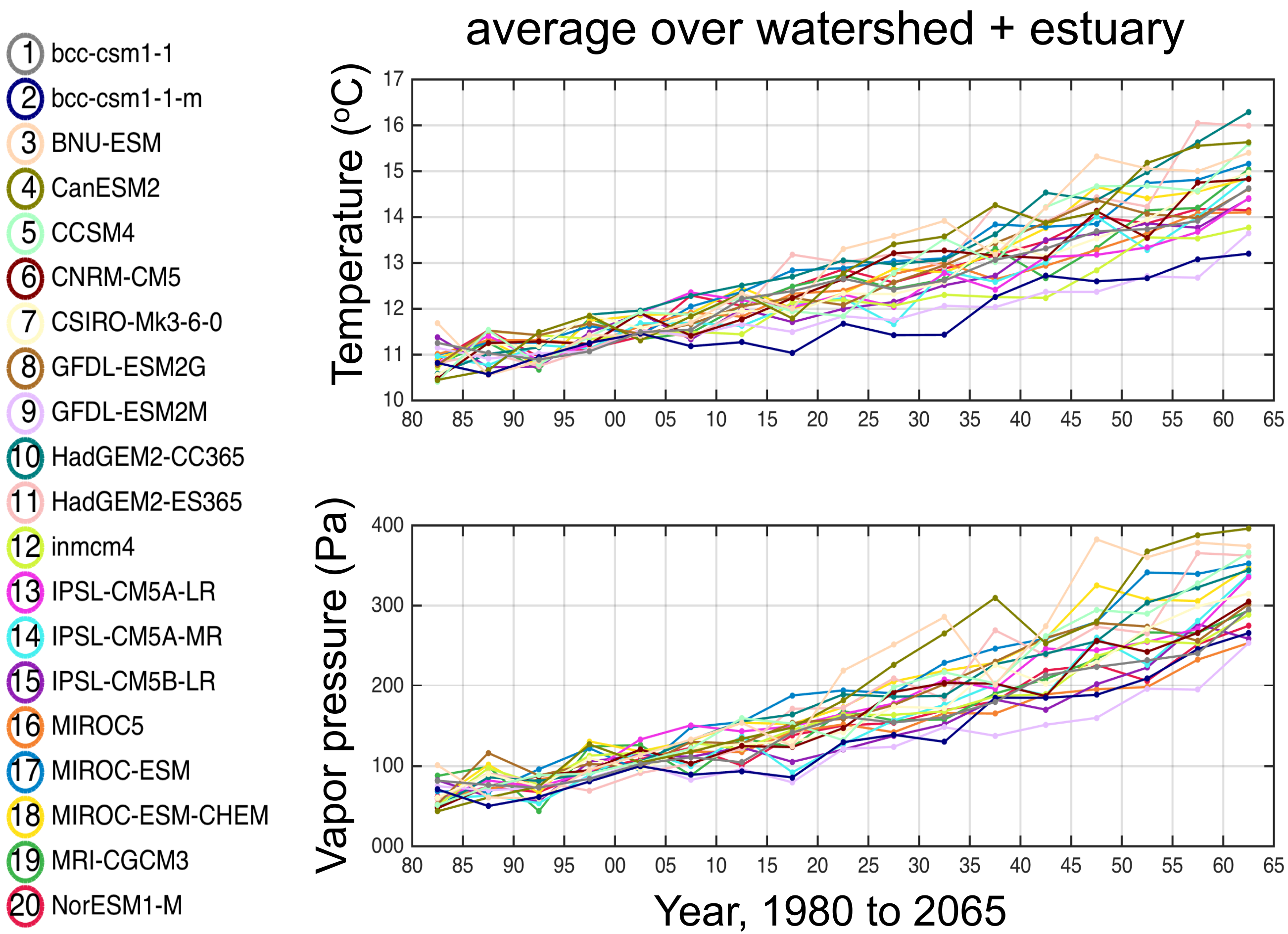
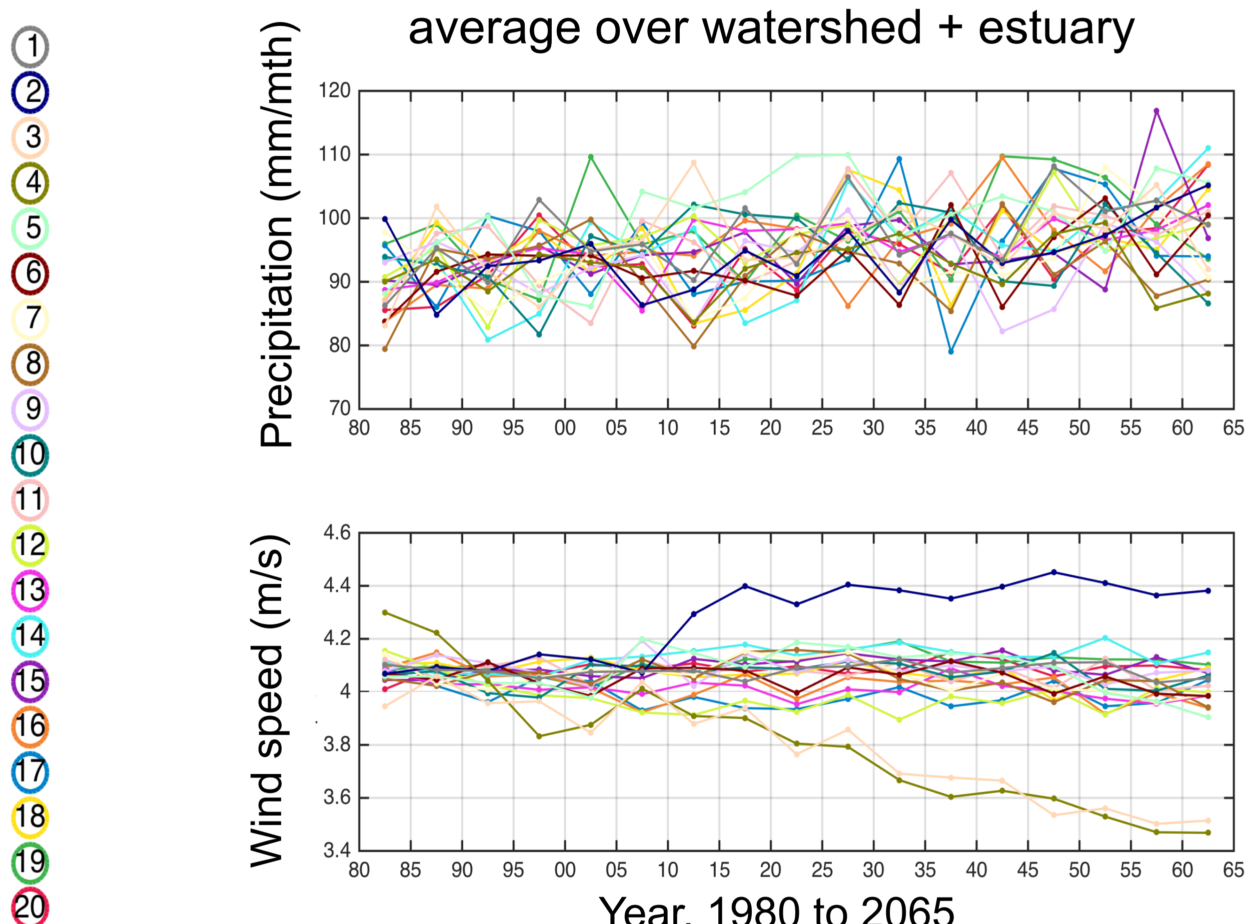
MACA downscaling of GCMs



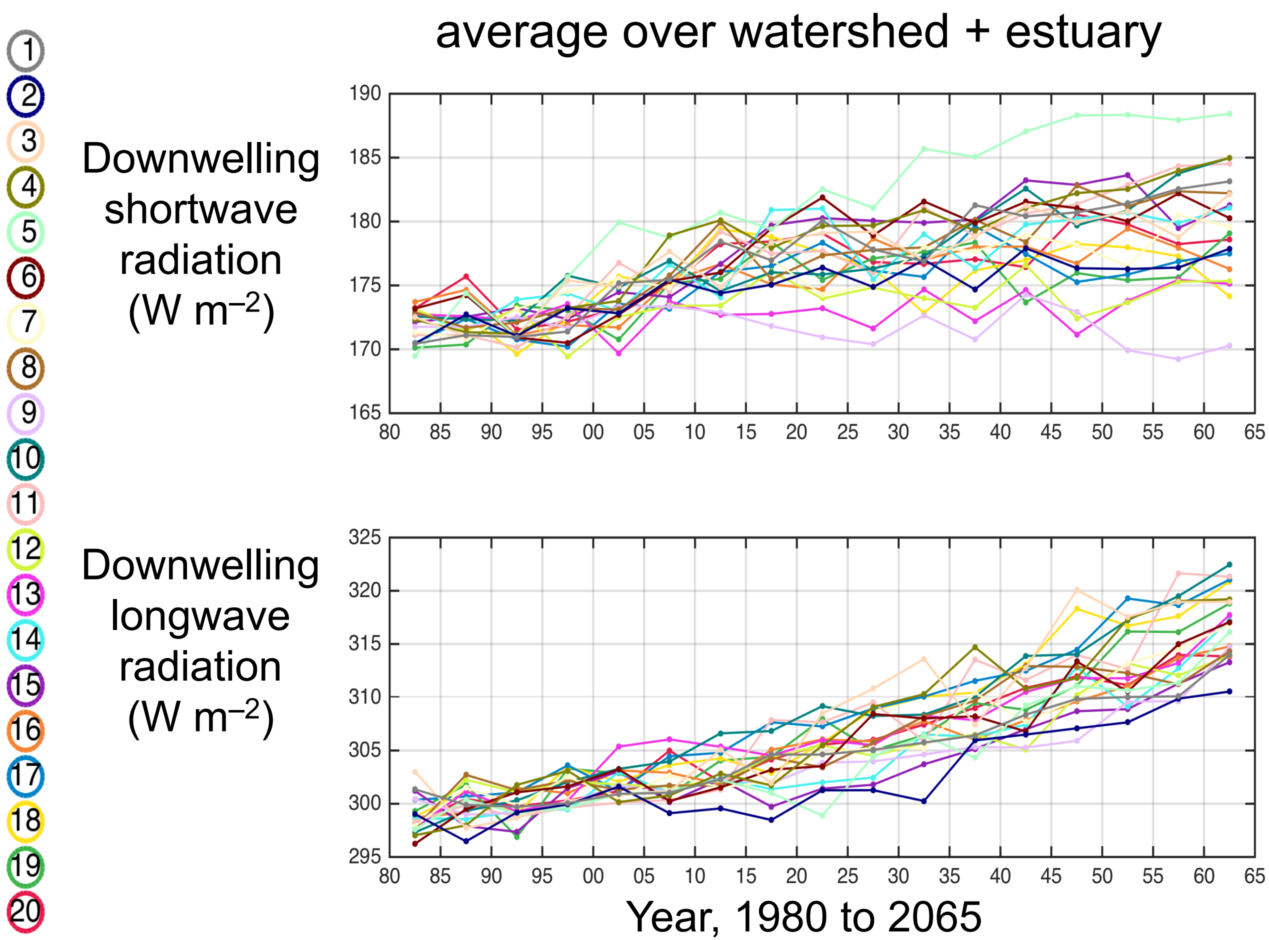
Clear increases in atmospheric temperature and humidity (1980-2065)

MACA downscaling of GCMs



Small changes in annual precipitation and wind speed (1980-2065)

MACA downscaling of GCMs



Increases in downwelling radiation (1980-2065)

CHAMP future simulations

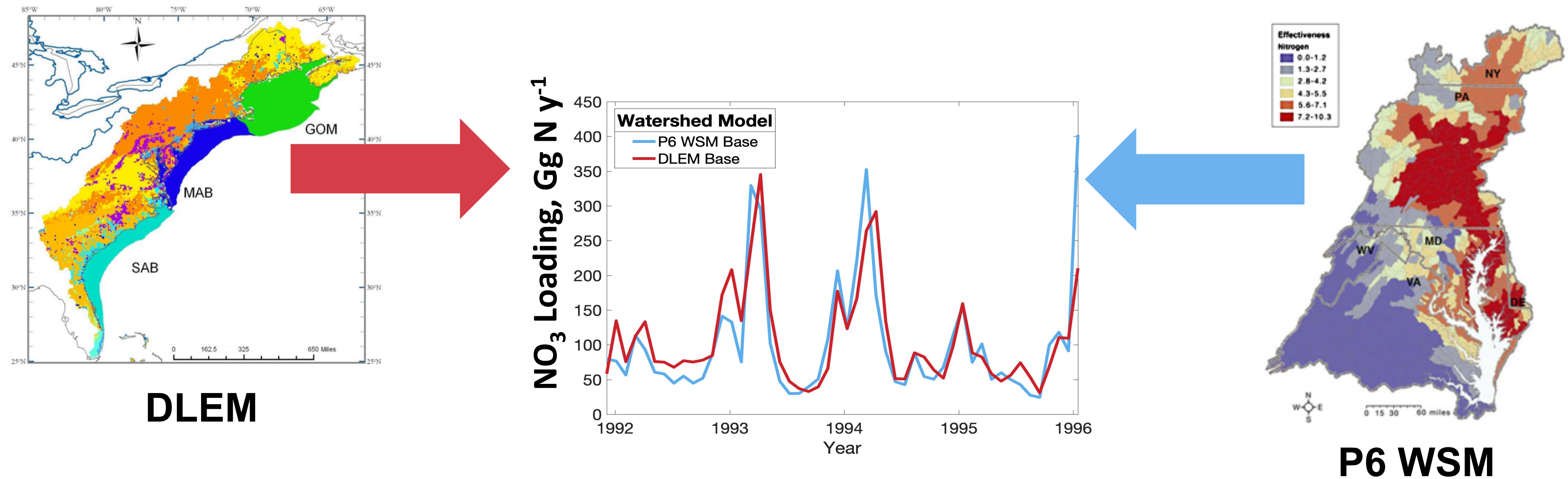
1. Delta approach:

- Select centroid of ~20 GCMs (KKZ approach)
- Compute “delta” of climate forcing from this GCM(s):

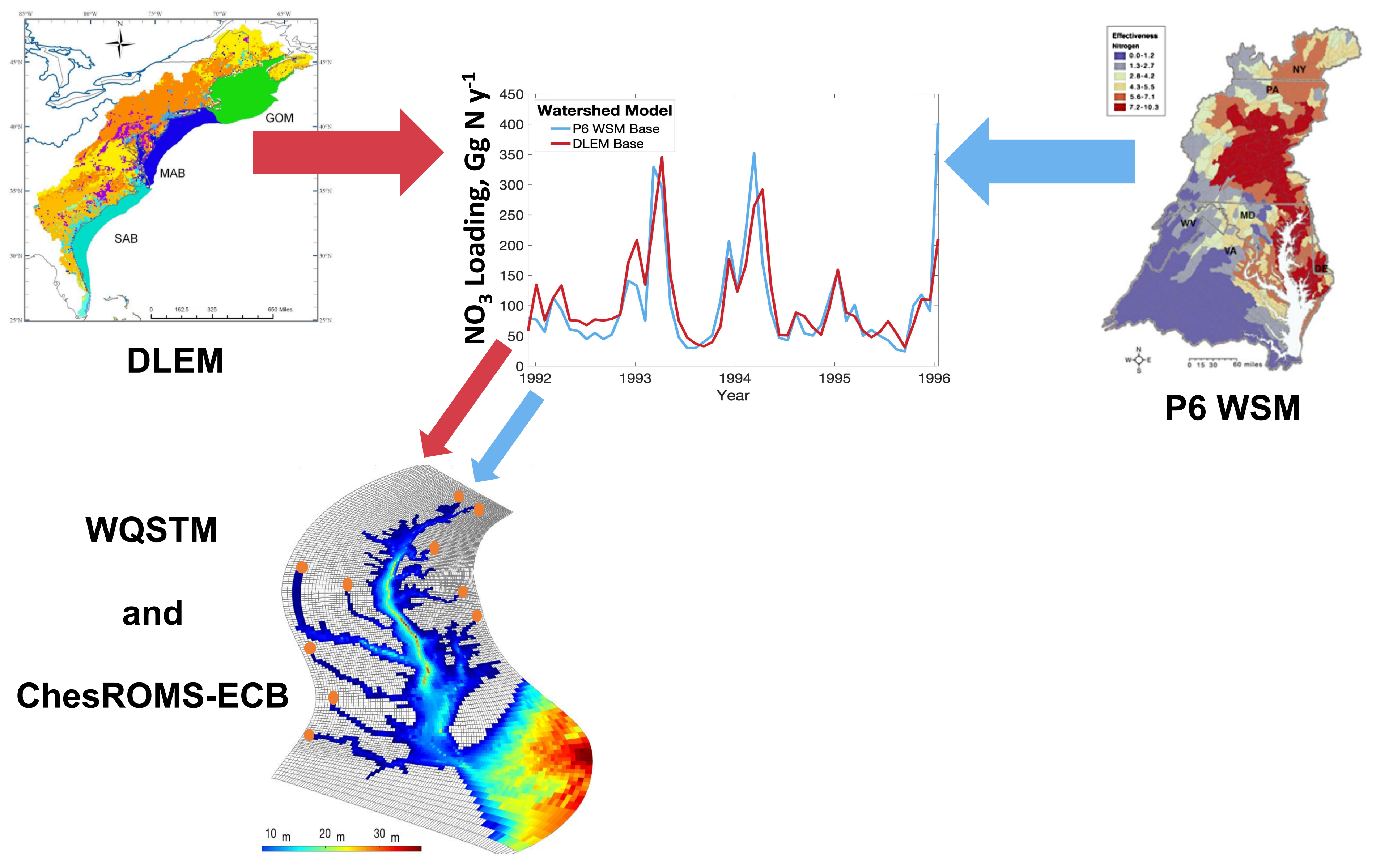
  delta = mean(2035 to 2065) – mean(1980 to 2010)
- Apply monthly “delta” forcing to 1991-2000 period
- Assumes past variability, e.g. in wet/dry years

2. Continuous forcing approach:

- Select centroid of ~20 GCMs (eventually more GCMs)
- Apply future forcing (daily, from 2015-2050)
- Includes future variability, e.g. in wet/dry years



GOM
MAB
SAB
0 162.5 325 650 Miles
DLEM
Watershed Model
P6 WSM Base
DLEM Base
NO_3 Loading, Gg N y^{-1}
0
50
100
150
200
250
300
350
400
450
1992
1993
1994
1995
1996
Year
Effectiveness
Nitrogen
0.0-1.2
1.3-2.7
2.8-4.2
4.3-5.5
5.6-7.1
7.2-10.3
NY
PA
MD
WV
VA
DE
0 15 30 60 miles
P6 WSM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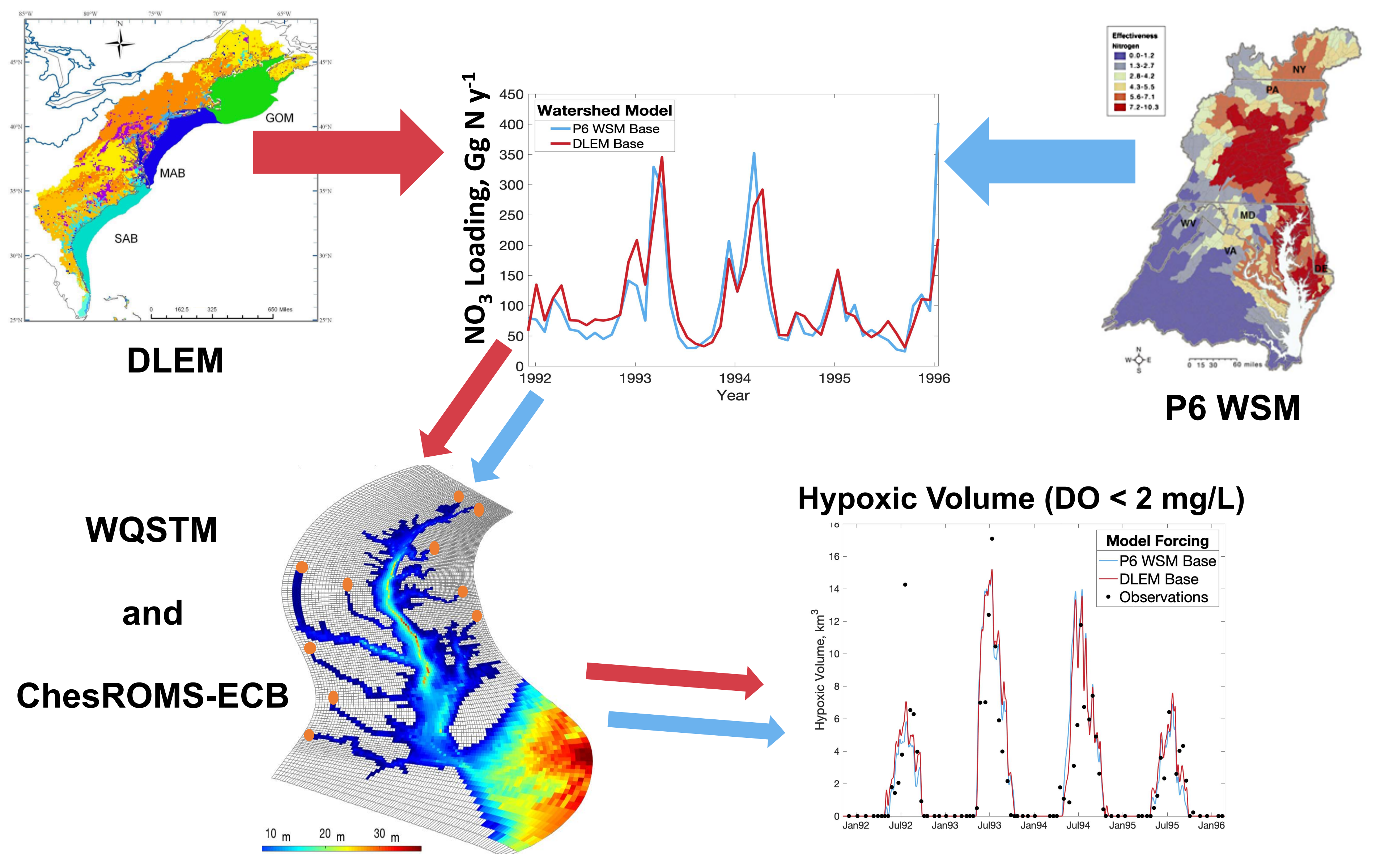

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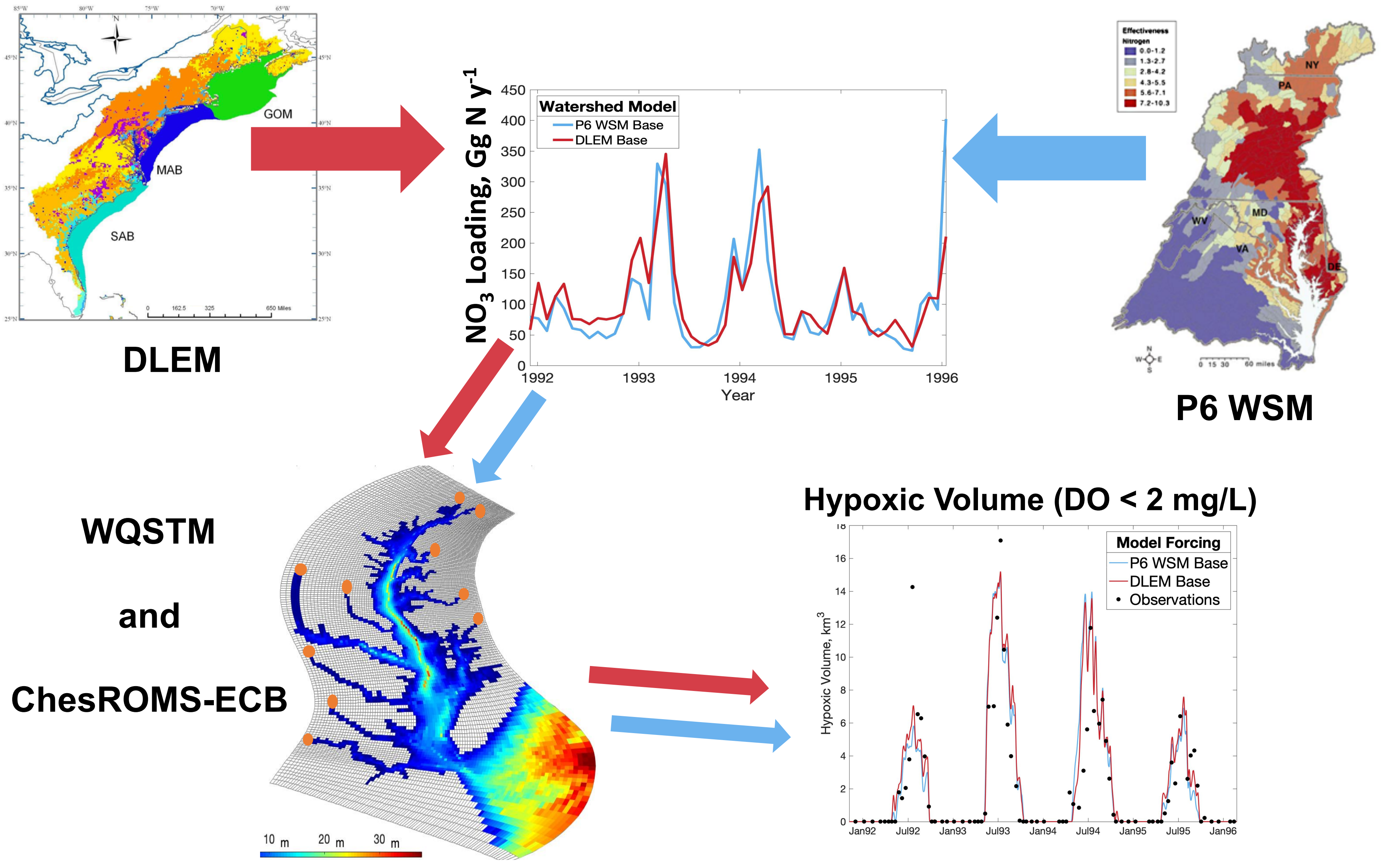
Hypoxic Volume (DO < 2 mg/L)
Model Forcing
P6 WSM Base
DLEM Base
Observations
Hypoxic Volume, km3
Jan92
Jul92
Jan93
Jul93
Jan94
Jul94
Jan95
Jul95
Jan96



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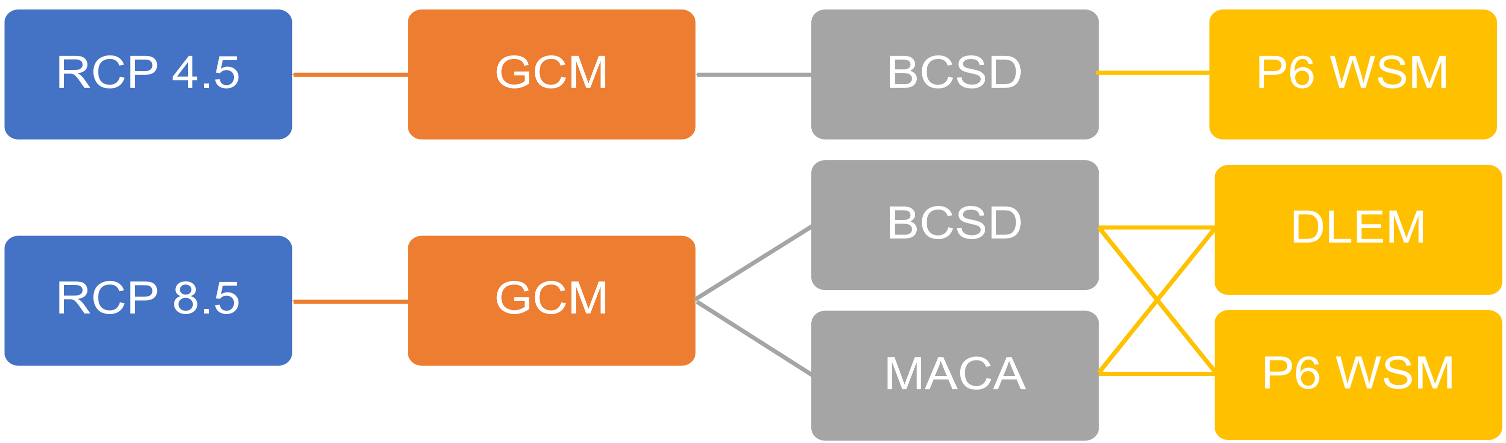
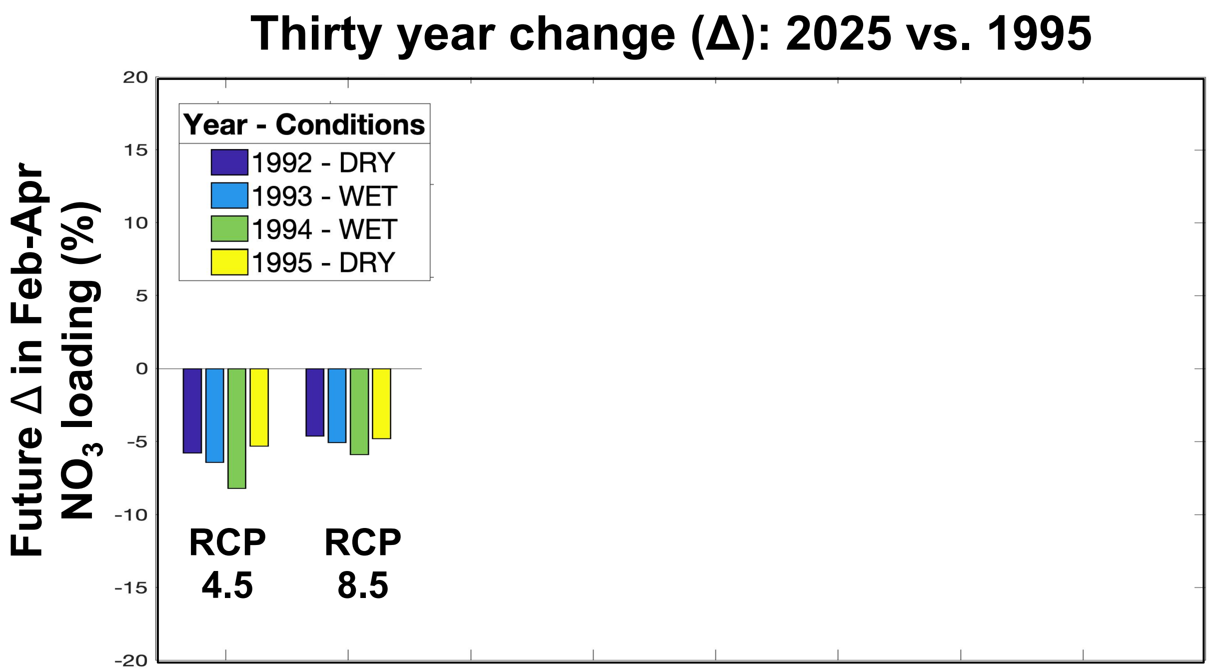
Impact of future uncertainty in climate forcing on hypoxia

2 CO_2 emissions scenario | **20 GCMs** | **2 downscaling techniques** | **2 watershed models**



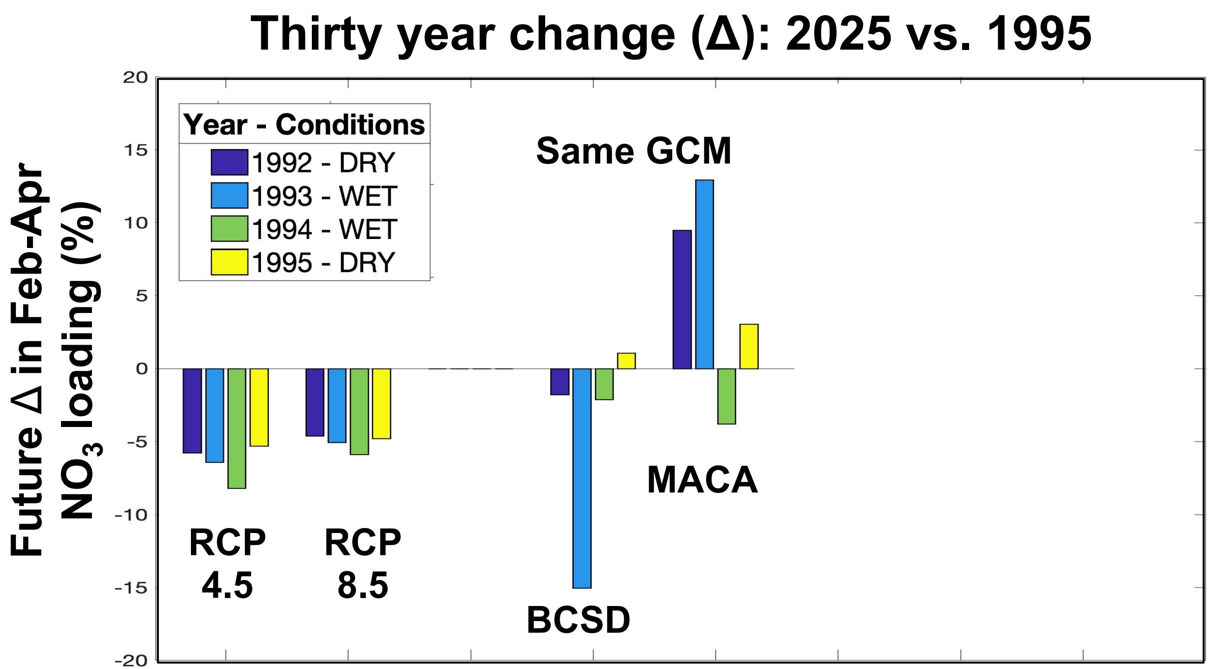
- Today focus only on P6 WSM (future work: DLEM comparison!)

Impact of future uncertainty in climate forcing on hypoxia



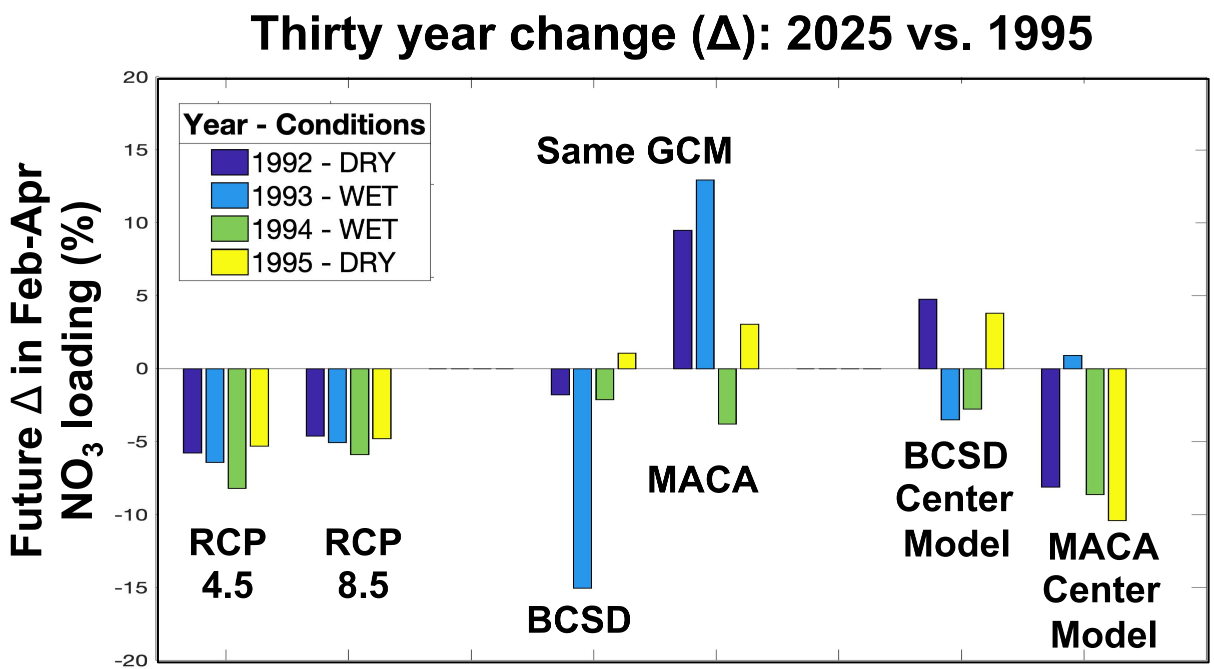
2025 Δ in NO_3 loading is: (i) relatively independent of emissions scenario

Impact of future uncertainty in climate forcing on hypoxia



2025 Δ in NO_3 loading is: (i) relatively independent of emissions scenario
(ii) highly dependent on downscaling method

Impact of future uncertainty in climate forcing on hypoxia



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(iii) less dependent on downscaling when Center Model is used (KKZ method, FMA precip, JJA temp)

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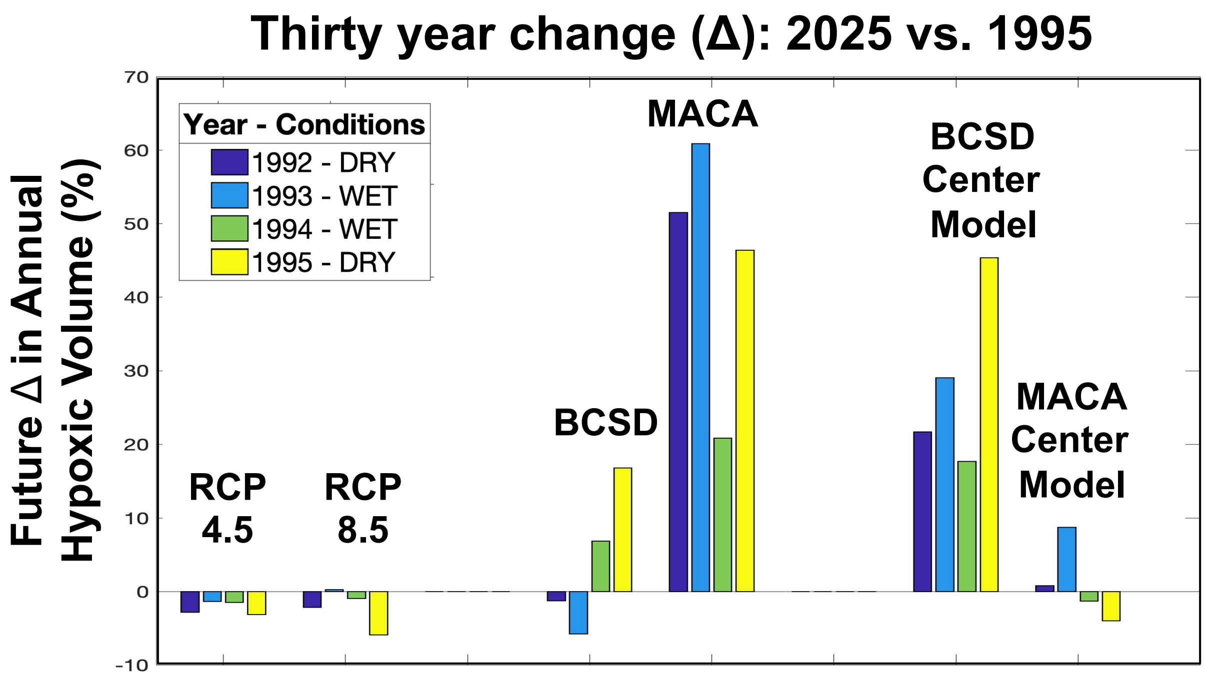

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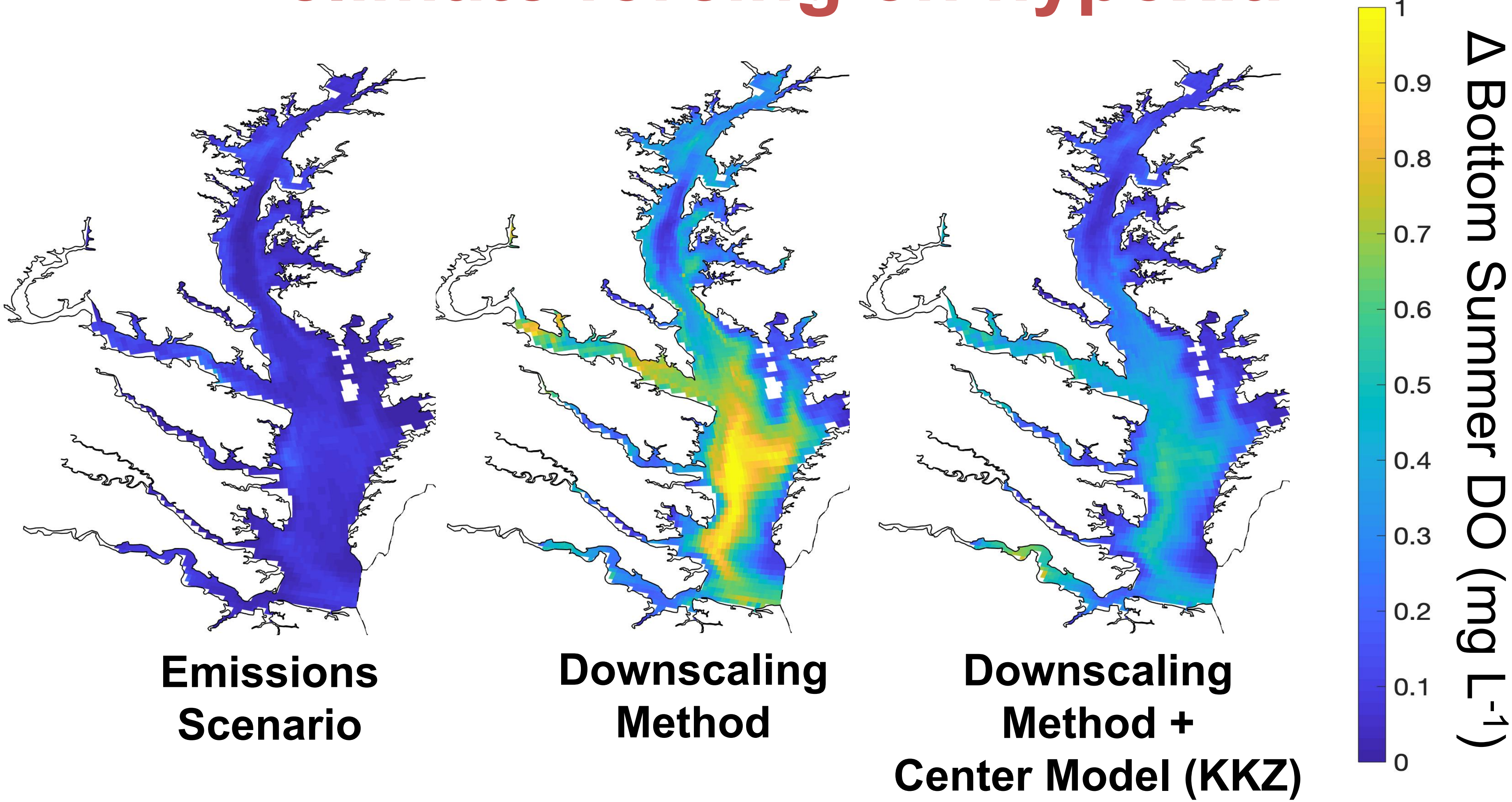

CHAMP – Future Work

Re-examine parameters for applying KKZ

- Use Nov-June precipitation, rather than Feb-April
- Use May-Oct temperature, rather than June-Aug

Apply other future forcing

- Radiation, winds, humidity…

Compare two watershed models

- CBP P6 vs. DLEM

Compare two estuarine models

- ChesROMS-ECB vs. WQSTM
- Apply future change to estuary as well

Continuous forcing approach

- Select centroid of 20 GCMs (or center 5 GCMs?)
- Apply future forcing (daily, from 2015-2050)

Extra Slides

KKZ diagram for MACA